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THE RESULTS OF DENTAL THERAPY IN FIFTY CASES OF AEROTITIS
MEDIA IN SUBMARINE PERSONNEL
BASED UPON
A NEW FUNCTIONAL CONCEPT OF EUSTACHIAN TUBE BLOCKAGE

Report No. I
on
Bureau of Medicine and Surgery
Research Project X-434 (Sub. No. 90)

Prepared by
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Interval Report No. 1
Bureau of Medicine and Surgery
Research Project X-434 (Sub. No. 90)
(Section b),

entitled

"Aerotitis Media in Submarine Personnel:
Relation of
Dental Defects and Mal-Occlusion to Eustachian Tube Failure"

Prepared by

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The Results of Dental Therapy in 50 Cases of Acrotitis
Media in Submarine Personnel
Based Upon
A New Functional Concept of Eustachian Tube Blockage*

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I. Summary.

In accordance with BuMed Project X-434 (Sub. No. 90) (b) Acrotitis Media in Submarine Personnel: Relation of Dental Defects and Malocclusion to Eustachian Tube Failure, work was undertaken to demonstrate the effectiveness of dental measures leading to the correction of defects so that the man could equalize air pressure and thus prevent the occurrence of acrotitis media.

In the present paper the problem is defined and the history of previous work is completely analyzed. The principal difference between the present approach and that used by previous investigators is the analyzing of all cases in function. The methods of diagnosis, x-rays in open and closed position, models mounted upon a moveable articulator follow this concept of motion. The treatment had for its objective the restoration of unstrained muscular activity and this was accomplished by freeing the lower jaw in functional occlusion to permit unhampered movements in all excursions.

With this restoration of unstrained muscular activity normal function was restored to the superior pharyngeal constrictor due to its interrelation with the buccinator through the pterygomandibular raphe, thereby stimulating lymph flow from the Eustachian tube and middle ear, relieving congestion in this area and restoring voluntary tubal patency, permitting equalization of the air pressure in the middle ear and in the surrounding atmosphere.

The measure of success in this experiment was entirely objective by means of a complete examination by a disinterested otologist.

Forty-six out of fifty carefully studied cases were successfully treated by this method.

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II. Definition.

Aerotitis media is the condition that results from a difference between air pressure in the middle ear and in the surrounding atmosphere. It is the difference in the two pressures, not the absolute value of either pressure, that calls forth the series of tissue changes known collectively as aerotitis media. Equalization of pressure normally occurs by the passage of air through the Eustachian tube during its momentary opening as in the act of swallowing or of yawning. Inability or failure to open the tube voluntarily at frequent intervals during a rapid change in pressure of the surrounding atmosphere is thus the inciting cause of the pressure differential that is the immediate cause of the lesions of aerotitis media. All efforts to prevent aerotitis media must therefore be directed toward maintenance, or restoration, of normal functioning of the Eustachian tube.(1)

III. History of Previous Work.

The possibilities of the dental correction of ear disturbances caused by variations in air pressure was first investigated by Willhelmy(2). He reported that the insertion of splints "to open the bite" in a small group of aviators with overclosure of the mandible appeared to give relief from distressing ear symptoms incident to rapid altitude changes. This same approach was used by Lowery (3) with a larger group (thirty-three) who had loss of intermaxillary distance. Of the twenty-six men submitted reports, nine stated that they were symptom free, fourteen felt some benefit from wearing the splints, and three derived no beneficial results. Teed (4) in a study of subjects at the Submarine Base, New London, following runs in the recompression chamber, wrote "Willhelmy believed that overclosure of the mandible might affect the proper functioning of the tube. In this series (seven hundred and eight) no such instance was recognized....I doubt very much if this condition could be classed among the causes of eustachian tube obstruction".

Other investigators (5) at a Naval Air Station stated that "the occurrence of ear block on low pressure chamber descents was found to occur five times as frequently in individuals with mal-occlusion as in individuals with normal occlusion".

Harvey and Morant (6) of the Royal Air Force stated that their experiments do not confirm these findings. They found that air crews with mal-occlusion outnumbered those with normal occlusion and that the incidence of otitic barotrauma (acrotitis media) was no more prevalent among men with mal-occlusion. Cases of otitic barotrauma had been fitted experimentally with "teeth splints" for flying; but none showed any resulting improvement. Cases of otitic barotrauma recovered without splinting after x-ray therapy to the lymphoid tissue at the orifice of the eustachian tube.

Captain C. W. Shilling (MC) USN (7), in charge of the Medical Research Laboratories, Submarine Base, New London, suggested that an effort be made to achieve a clarification of these divergent views. One of the writers was therefore ordered to duty at this activity to conduct a thorough investigation of the possibilities of the dental correction of the causes of acrotitis media.

IV. Background of Present Project.

The rigid physical examinations and screening tests employed in submarine examining at the Medical Research Laboratories excluded all candidates except young healthy normal males. Included in these examinations were audiometric studies of every man by the Sound Laboratory of Medical Research and a loss of more than 20 decibels in all tones below 4096 double vibrations per second was considered cause for rejection.

Thus many extraneous factors were initially eliminated and a wealth of good clinical material was available in that all candidates for submarine training are required to take 50 pounds air pressure in a recompression chamber to qualify for instruction in the use of the escape lung. This is three times the pressure that any aviator could possibly be exposed to on descent and therefore would provide a thorough test of any corrective measures employed. The first step in the project was to review available articles (8) on Aviation Dentistry relating to acrotitis media. This review revealed a number of points common to all articles as follows: (a) all conclusions were based upon subjective symptoms, relying on whether the man stated his ears had or had not improved following treatment; (b) that the classification of mal-occlusion was based upon a static relationship of the jaws; (c) cases were selected with overclosure of the mandible; and (d) that x-rays of the temporomandibular articulation in open and closed positions were not utilized as diagnostic aids.

With these points in mind and to rule out as many variables as possible, this investigation was accomplished as follows:

- (a) those men with any interference in mandibular function who showed acrotitis media following exposure to pressure were taken at random for treatment. No effort was made to select cases on any other basis, such as amount of adenoidal tissue, history of ear disease, etc.
- (b) subjective symptoms were not used as a criterion of success or failure, as they might be unreliable. That only objective symptoms would count, i.e., the appearance of previously affected ears, otoscopically, when repressured following dental treatment.
- (c) all results were checked by an otologist, independently of this investigator.
- (d) all men were given uniform instruction in the valsalva maneuver to clear their ears, before going into the chamber.
- (e) successful cases, (if any) were to be rechecked through the chamber some months later to determine what degree of permanency was afforded by the treatment.
- (f) all cases of acrotitis media were graded from 0 to 5 depending upon the amount of ear damage shown otoscopically after exposure to pressure, and that this same classification be used for determining the success or failure of treatment. This classification follows:

- Grade 0 - Normal.
- Grade 1 - Retraction with redness in Shrapnell's membrane and along the manubrium.
- Grade 2 - Retraction with redness of the entire drum.
- Grade 3 - Same as grade 2, plus evidence of fluid and hemorrhage in the drum.
- Grade 4 - Hemotympanum; perforation of the drum of both.
- Grade 5 - Drum blue black in color and tympanum filled with a sero-sanguinous fluid, but no air bubbles.

- (g) all cases be checked with a nasopharyngoscope, as

an otoscope, before and after treatment.

(h) control groups were established as follows:

- (1) an untreated group that did not have aerotitis media on the first chamber run, to be re-pressured at intervals.
- (2) an untreated group that did show aerotitis media on the first chamber run, to be re-pressured at intervals.

V. Functional Concept of Eustachian Tube Blockage.

The second step, after setting up the project was to consider previous theories advanced as to why a change in jaw relationship could favorably affect stenosis of the eustachian tube.

The rationale for the methods used by Willholm and Lowery was based upon the Costen hypothesis (9) which postulates that in cases of overclosure of the mandible the internal pterygoid relaxes and crowds the soft tissue against the pharyngeal opening of the eustachian tube, causing a mechanical obstruction, and that the insertion of splints to restore this lost dimension corrected this condition enabling the men to ventilate the middle ear.

Seaver (10) believed, that as the tensor palati muscle (considered as the most important of the three muscles opening the tube) received its innervation from the fifth cranial nerve it will be affected by painful stimulation of the sensory distribution of the fifth nerve, especially the mandibular division, and that this painful stimulation would be present in mal-occlusion. He further stated "as stuffiness of the middle ear is a common complaint in mal-occlusion it is assumed that the function of the tensor palati muscle in opening the tube may be inhibited".

These theories did not completely satisfy the requirements of this project as the one (Costen's) was controversial, and the other did not allow for cases of mal-occlusion that showed no aerotitis media as reported by Harvey and Morant.

Doctor Stacey Guild of Johns Hopkins then suggested to one of the writers, that as there is usually some edema of the eustachian tube in cases of acroitis media, this congestion might be due to stasis of the lymphatics draining the tube and that mal-position of the jaws might be a factor.

This sounded like a logical possibility and a review of the available literature on the lymphatics revealed the following:

Most (11) states that "the lymph vessels in the middle ear connect through the lymph capillaries of the eustachian tube with those of the lateral pharyngeal wall....that they pass the rear circumference of the tube, through the cartilagenous wall and travel between it and the bone to the lateral pharyngeal gland which lies in the bucco-pharyngeal fascia. THE LATERAL PHARYNGEAL GLAND IS THE FIRST AND MOST IMPORTANT LYMPH NODE DRAINING THE EUSTACHIAN TUBE AND MIDDLE EAR".

Grays Anatomy (12) shows that the superior pharyngeal constrictor forms the lateral walls of the pharynx and that the lymph channels passing to the lateral pharyngeal lymph node are affected by the movements of this muscle.

Concerning the relation of this muscle to the muscles of mastication Shapiro and Truex (13) have this to say "In working with this specimen we were particularly impressed with the alternate tense and lax condition of the superior pharyngeal constrictor muscle as the mandible was moved from side to side. When it is recalled that this muscle is continuous with the buccinator through the pterygomandibular raphe, tenseness of the constrictor is readily understood as playing a secondary role to the pull of the buccinator during movements of the mandible".

As to the relation of muscle activity to the flow of the lymph, Starling (14) has written this "The only part of the body which has a continuous flow of lymph during rest is the alimentary canal....since the lymphatics are all provided with valves the effect of external pressure on them is to cause the lymph to flow in one direction only, towards the thoracic duct and great veins. HENCE WE MAY LOOK UPON MUSCULAR ACTIVITY AS THE GREATEST FACTOR IN THE CIRCULATION OF LYMPH."

From this material we concluded that any conditions that interfered with the normal function of the buccinator would in turn affect the superior pharyngeal constrictor, and by inhibiting its movements might produce a congestion of the eustachian tube due to a stasis of the lymphatics caused by insufficient muscular activity.

The next consideration, then, was that we were dealing with motion and any attempt to approach the problem from a static concept might end in failure.

VI. Experimental Technique Used.

After a selection of a patient with aerotitis media and following the concept of motion, x-rays of both temporomandibular articulations, using the mastoid approach from the opposite side, were taken in both open and closed positions.

With a suitable material, impressions of both jaws were taken and casts run up in stone. It was then necessary to select an instrument upon which the models could be placed so that the relationship of the jaws could be studied in motion and the findings correlated with the x-ray plates.

Because the temporomandibular articulation is an arthrodialdiathrosis joint, its movements are necessarily very complex and no instrument has yet been developed that fully reproduces all these movements. A Hanau articulator was selected because it produces equivalent movements of the mandible which proved quite satisfactory for this purpose, due to its simplicity and accuracy.

The next step was to transfer the upper cast to the articulator with the aid of a face bow. The purpose of this was to have the upper case in the same relation to the hinge of the articulator as the maxilla is to the temporomandibular articulation.

The mounting of the lower cast is important in that all registrations should be taken in unstrained positions for accuracy. This is necessary because the magnitude and direction of force and their points of application during a registration are beyond the control of both the operator and patient. It is logical to assume, therefore, that methods to record jaw

relationships with pressure may be unreliable. Of all the magnitudes, directions, and points of application of forces that a patient can possibly exert, there is only one reliable and definite combination, and that is, the magnitude of the force Zero, a force which has no direction or point of application.

With this in mind, the patient was placed in a relaxed, upright position, instructed to swallow, open to a rest position, and allow a thin piece of low fusing wax to be inserted between the arches, and then instructed to close gently until the first point of contact was made through the wax by any two or more opposing teeth, but no further closure was permitted. The wax was then chilled and carefully removed. This was repeated until two or more "bites" agreed.

It is realized that biting into wax requires the application of some force and in order to reduce this as much as possible, a very soft heated wax was used and the patient instructed to close gently.

The condyle paths on the articulator were then set by having the patient protrude the lower jaw and made new wax registrations in this position and the articulator adjusted accordingly. Lateral settings on the articulator were determined by the formula $L = \frac{H}{8} + 12$, where:

L is the lateral condyle inclination in degrees;

H is the horizontal condyle inclination in degrees as established by the protrusive relation;

(a full explanation of the operation of this formula is contained in the instruction book (15) accompanying each Hanau Articulator).

A study was then made of this relationship on the articulator and the points of premature contact were marked and compared in the mouth. The models were then run through all paths of excursion and any point of interference noted.

These points were then checked in the mouth by having the patient duplicate the movements with carbon paper between the teeth. The inclined planes of the teeth around the point of premature contact were studied on the models and in the mouth. Then with a small stone interfering inclined planes were reduced to provide unhampered excursions.

The vertical dimension in static occlusion was not altered in any way, since the cuspal points or occlusal sulci were not touched. Only planes which offered resistance to free excursion were reduced.

All cases were carefully studied for possible overclosure or loss of intermaxillary distance by the following methods:

- (a) Appearance of the patient;
- (b) Possible superior displacement of the condyle heads in the fossae as revealed by the x-rays;
- (c) Gnathodynametric readings (16) to locate that occlusal relationship (vertical dimension) which allowed the maximum biting force to be registered, less the normal free way space;
- (d) Missing posterior teeth which often pointed to a possible loss of this dimension.

The previous dental approach to this problem has dealt almost exclusively with the insertion of splints to "open the bite". We feel that the widely divergent views as to the efficacy of this procedure and poor degree of success, or lack of it, in the hands of some investigators may be attributed to the fact that splints were used in cases where they were not indicated and by over-opening increased strained articular relations, thus further aggravating an already abnormal situation.

We believe that the use of splints is a definite adjunct to the dental treatment of acrotitis media in some cases. Splints should only be employed, however, where indicated and great care must be exercised not to open beyond normal limits and to maintain a correct free way space. Over opening of this distance due to tilting and drifting of teeth and/or other causes was carefully watched for.

VII. Experimental Results.

Over a period of ten months, fifty cases of acrotitis media were treated using the foregoing technique. Following dental treatment the men were given 50 lbs pressure and when they emerged from the chamber their ears were checked by the Medical Research Otologist, otoscopically. Any man showing a #1 ear, either unilaterally or bilaterally, was regarded as an unsuccessful case.

This was a very high standard to meet as a #1 ear shows only a pinkness around the periphery of the drum and along the handle of the malleus and a man could give himself this type of ear while under pressure when executing the Valsalva maneuver if there was the slightest degree of eustachian tube blockage. Forty-six of the fifty cases, however, came through pressure after treatment with absolutely negative or #0 ears, whereas before treatment the ear damage had ranged from #3 to #5 ears either unilaterally or bilaterally.

In these 46 successful cases the conclusions were based upon objective findings, i.e. otoscopic examination, which is the only reliable criterion of the success or failure of any treatment for acroitis media. We found that little reliance could be placed upon subjective symptoms because many men took 50 lbs pressure and on leaving the pressure chamber stated that their ears felt normal and that they had no pain or discomfort; even when otoscopic examination showed that they had #3, #4 or #5 ears. This could be partially accounted for by the universally high motivation among the candidates, and fear of disqualification for submarine duty.

In this series of 46 cases we found 5 where there was an overopening of the intermaxillary distance caused by the early loss of six year molars and the subsequent tilting and drifting of other teeth in the molar region. These cases were treated by the reduction of the occlusal surfaces of the offending tooth or teeth or by the removal of third molars so that a more normal vertical dimension was restored; this, plus the removal of lateral prematures, was sufficient to create a successful case. These 5 cases were of great interest to us as the possibility of overopening of the intermaxillary distance had never previously been considered as a possible factor in acroitis media. Following any other concept but a functional one this factor would have been ignored and we believe that this accounts for failures where splints are used indiscriminately.

In only 3 of the 46 cases were splints employed. In each of these a number of molar teeth were missing and superior displacement of the condyle heads could be demonstrated in

the glenoid fossae radiographically. In each case post operative x-rays were taken as a check. The splints in each case were so constructed that the resulting occlusal plane was in harmony with the mechanical and physiological requirements of the temporomandibular articulation thus permitting unhampered excursions of the mandible and complete function of the buccinator.

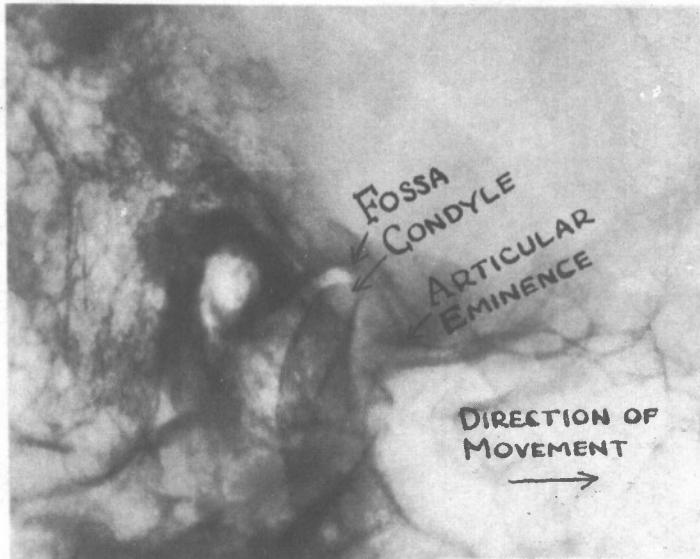
Figures #1 through #8 show the x-rays of one of the three cases and illustrate the importance of properly projected radiographs in the diagnosis and treatment of these conditions.

In this group of cases all types of adenoids were found, ranging from enormous to small. In 20 of the patients the adenoids were enormous and covered the ostium of the tube. Because of this we have failed, so far, to find any correlation between the type of lymphoid tissue found in the nasopharynx and the success or failure of a dental treatment that follows these methods of diagnosis and proscription.

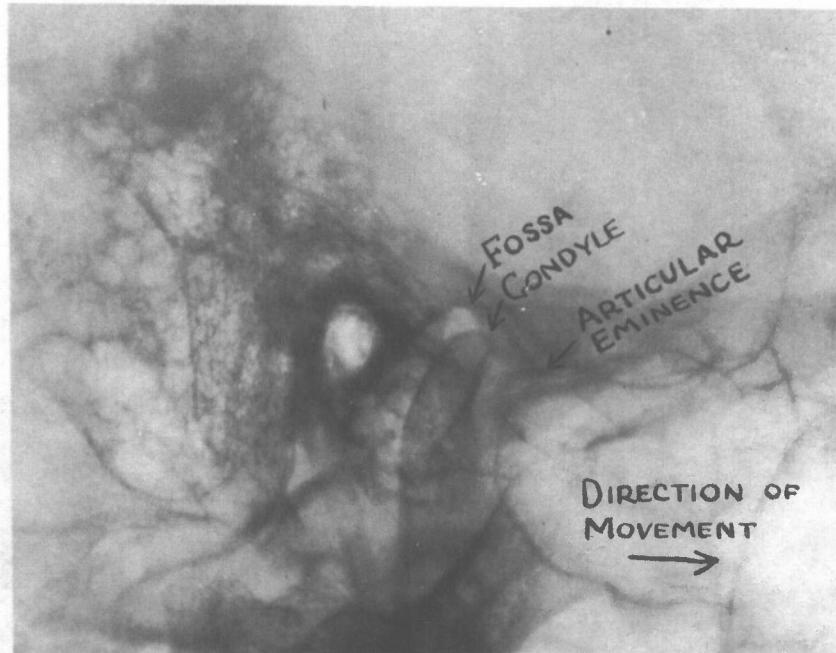
A number of the cases of acrotitis media (ten) judged according to the standard static concept of occlusion would be classed as normal, but when studied in motion pronounced prematures and interfering contacts could be demonstrated causing the condyle heads to assume strained articular relations, motivated in many instances by aberrant inclined planes found on large occlusal inlays and amalgam restoration. Reduction of the inclined planes to provide unhampered movement in all excursions was sufficient treatment.

It was further noted in this series that where there was unilateral acrotitis media, that the occlusal interference in lateral excursion was always on the side away from the affected ear, while in lateral movement on the side away from the normal ear there was little interference. These cases were treated by simply removing the lateral prematures on the one side.

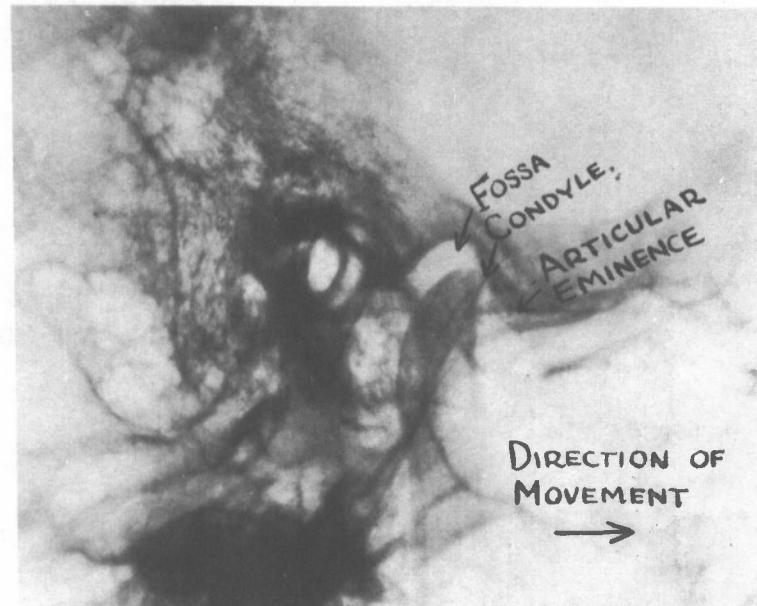
There were four of the fifty cases that were classed as unsuccessful. Three of the four yielded to radium therapy applied to the pharyngeal orifice of the Eustachian tube. In the fourth case radium therapy was as unsuccessful as dental treatment.



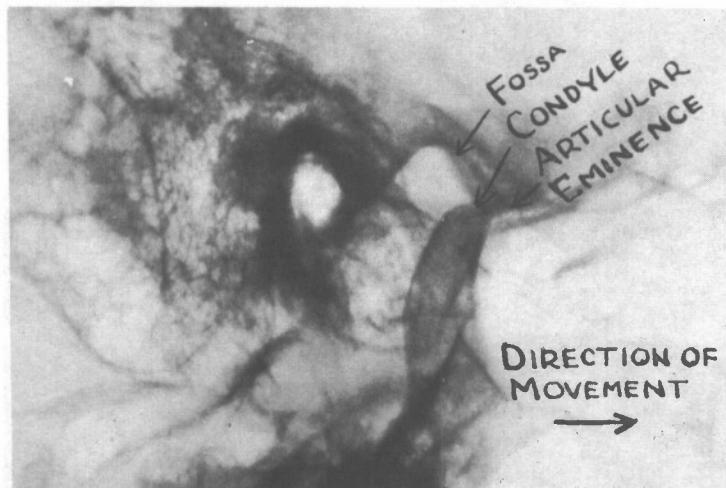
1. Right side, closed position before treatment, the condyle head is superiorly displaced in the glenoid fossa.



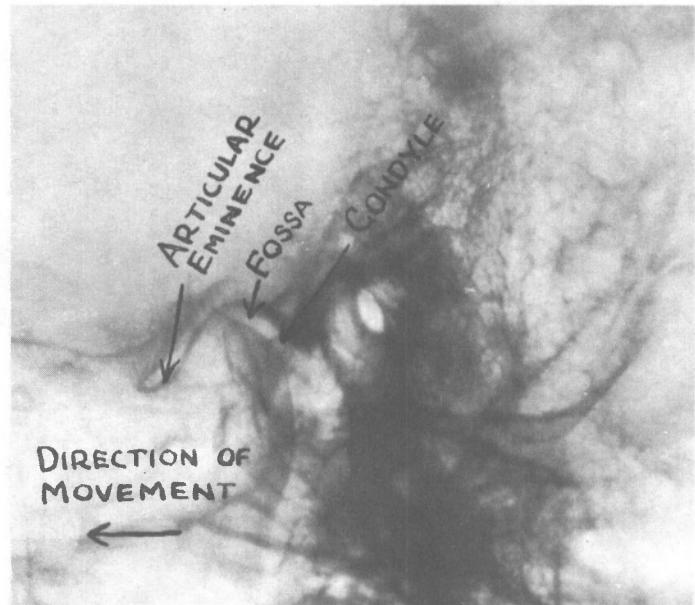
2. Right side closed position after the insertion of a dental splint. Note how the condyle head has begun to assume a lower and more normal position in the fossa.



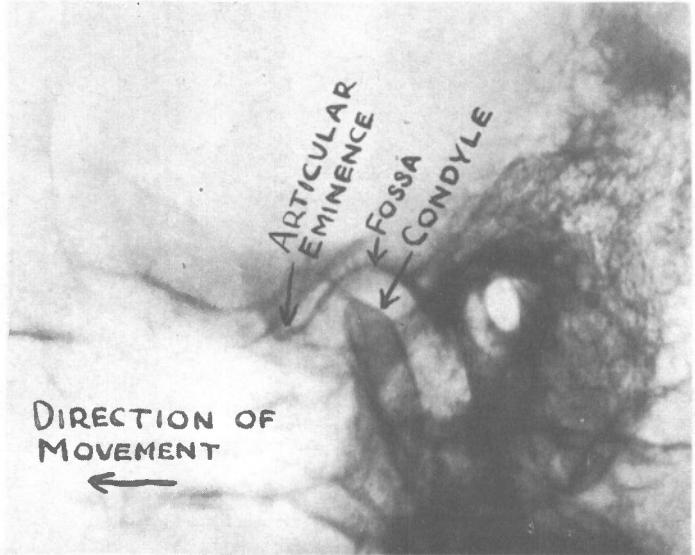
3. Right side open position before treatment. The condyle head is unable to leave the fossa, possibly blocked by a traumatized meniscus or disk caused by continued occlusal disharmony.



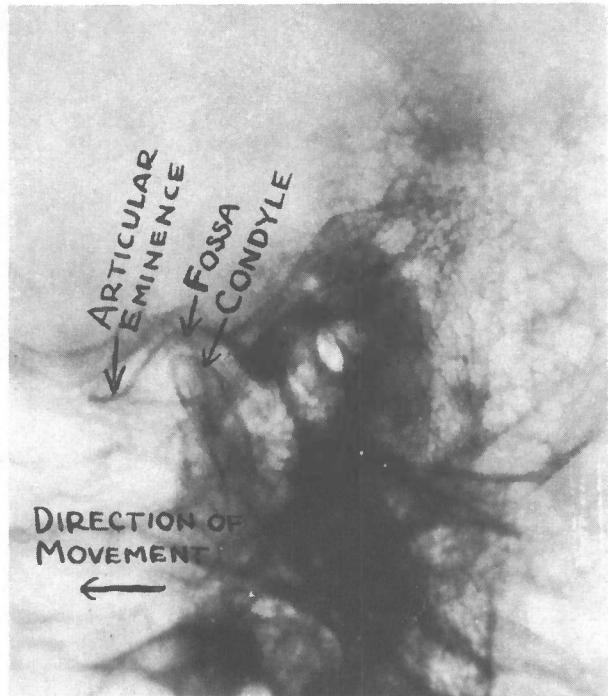
4. Right side open position after the insertion of the splints. The condyle now is able to make an excursion and assume a position below the articular eminence.



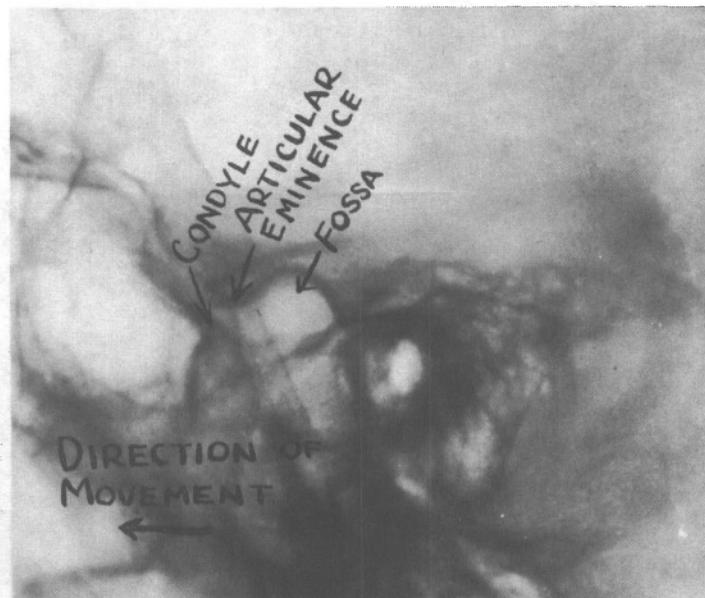
5. Left side closed position before treatment. The condyle head has a superior displacement in the fossa.



6. Left side closed position after the insertion of the splint. The condyle head is now lower and in a more normal position in the fossa.



7. Left side open position before treatment. The condyle is unable to leave the fossa and is impacked against the anterior wall of the fossa. This position possibly accounted for a recurrent otalgia complained of by the patient.



8. Left side open position after the insertion of the splint. The condyle is now able to make a more normal excursion and the symptoms of otalgia have subsided.

Included in the series of 46 cases were two that had a number of radium treatments but still showed aerotitis media when repressured these responded to dental treatment.

Control Groups:

1. The untreated group that did not have aerotitis media on the initial chamber run was repressured at intervals with no significant deviation. This held true as well for the untreated group that did show aerotitis media on the initial run.

2. In an attempt to rule out any psychic factors in dental treatment a group of ten men was taken who had experienced so much discomfort in the pressure chamber that they were released before reaching 50 lbs. showing #3 to #4 ears bilaterally. Nothing was done to change the existing jaw relationship but the men were unaware of this; they were led to believe that a thorough dental treatment had been carried out. The group was then repressured and on leaving the chamber all showed the same type of ears as they had on the first run. The only difference was that five of the men "stuck it out" to 50 lbs. We were able to get five of the men and institute regular dental procedures and then repressure them. Examination of the ears showed them all to be negative. This led us to a conclusion that any psychic factor involved might assist a man to withstand pressure to 50 lbs., but would not affect the degree of acrotitis media.

3. We were able to repressure 10 of the 46 cases, some four months after treatment, and the ears were still negative and we were led to believe that the effects of the treatment are permanent in nature.

VIII. Additional Observation.

Mal-Occlusion both Static and Functional, but no Aerotitis Media:

Many cases were seen (not in this series) where there was definite static and/or functional mal-occlusion and the men came out of the pressure chamber with unaffected ears. All types of adenoidal tissue was present. Temporomandibular x-rays of a number of these cases (twentv-five) in both open and closed positions disclosed uniformly flat fossae, presenting no mechanical problem to any sort of movement.

CONCLUSIONS

1. Successful treatment of aerotitis media, using those dental methods of diagnosis and treatment, has been demonstrated in 46 out of 50 cases where the problem is approached on the basis of functional rather than static occlusion.
2. Because one control group with aerotitis media on their initial chamber run, continued to show approximately the same degree of ear damage when repressured at intervals after a complete recovery and without any corrective treatment; we believe that the series of 50 cases, reported in this paper, would have continued to show aerotitis media on repeated chamber runs if no dental treatment had been instituted.
3. We believe we have shown that the elimination of functional restrictions of the buccinator, and hence the superior pharyngeal constrictor due to their interrelation through the pterygo-mandibular raphe, by dental equilibration and/or restoration of a normal vertical dimension of the jaws; re-establishes the "milking" action on the lymphatics, thereby stimulating their drainage and thus reducing edema and congestion of the eustachian tube and middle ear.
4. We also believe that further substantiation of the theory of lymphatic stasis is borne out by the fact that the amount of lymphoid tissue had little bearing on the success or failure of this method of dental treatment.
5. In cases where the glenoid fossae are flat, there appears to be little mechanical interference with mandibular motion; despite the type of malocclusion present, either functional and/or static with slight evidence of lymphatic congestion shown.

* * * * *

Grateful acknowledgement is made to Captain C. W. Shilling, (MC) USN, for his advice and cooperation in making this project possible; to Doctor Stacey Guild for his invaluable help during the project and his assistance in preparing this paper; to Lt. (jg) Henry L. Haines, (MC) USNR, who placed his knowledge and skill at our disposal; and to Doctor Henry W. Langheinz, who devoted many hours to this project in the compiling and translation of references, in rendering major assistance in solving many difficult problems, and in contributing materially to the preparation of this paper.

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